PB81-213332

Improvement of Magnetically Separated Ferrous Concentrate by Shredding: A Performance Test Test No. 4.07, Recovery 1, New Orleans

National Center for Resource Recovery, Inc.
Washington, DC

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

Jun 81

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-81-103	2. ORD Report	3. RECIPIENT'S ACCESSION NO. PB81 213332
4. TITLE AND SUBTITLE Improvement of Magnetically Separated Ferrous Concentrate by Shredding: A performance test. Test No. 4.07, Recovery 1, New Orleans		5. REPORT DATE June 1981
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Kelly Runyon		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS National Center for Resource Recovery Washington, D.C. 20036		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-01-4423
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory - Cin.,OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED
		14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES See also EPA-600/2-81-100, EPA-600/2-81-101, and EPA-600/2-81-102

Project Officer - Donald Oberacker 513/684-4417 (Carlton C. Wiles 513/684-7871)

16. ABSTRACT

This report describes a series of test runs (taken collectively as Test No. 4.07) in which ferrous product magnetically recovered from municipal waste was further shredded in a small (50 hp) hammermill to free attached or entrapped contaminant. A belt magnet was then used to separate metal from the liberated contaminant.

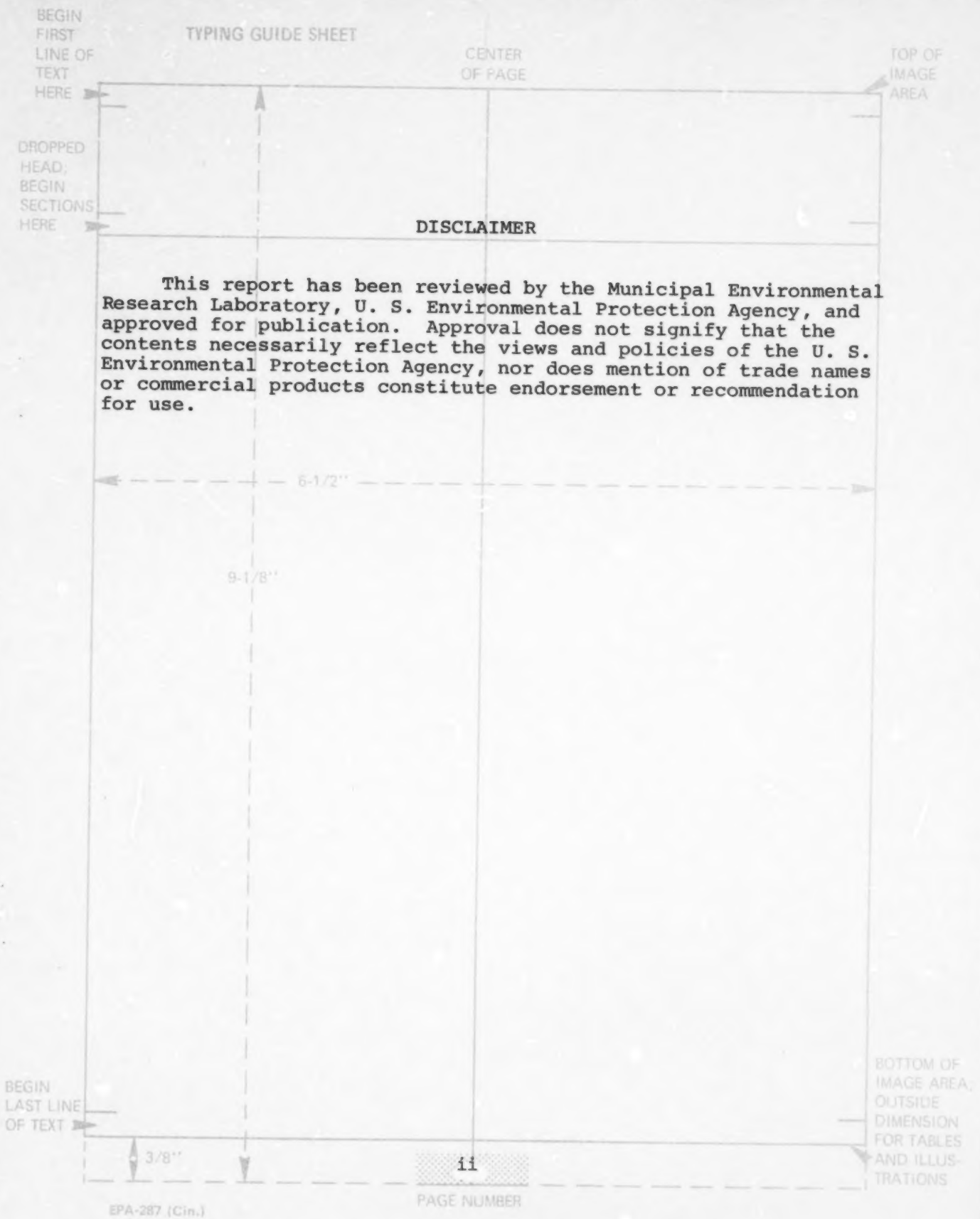
This report details test results and describes the equipment used, test procedures, and methods of sample analysis. Results indicate that the apparatus performs well and produces a marketable product. In addition to measuring contamination, particle size, nuggetization, and density, tests were run to assess hammer wear, energy consumption, performance during surges in feed, and performance with unusually large or dense items augmenting feed material.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Resource Recovery Solid Waste Shredders Size Reduction Wear Material Recovery	Size Reduction Solid Waste Shredder Design Resource Recovery	13 B

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release to Public	Unclassified	59
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (9-73)



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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources; for the preservation and treatment of public drinking water supplies; and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research, a most vital communications link between the researcher and the user community.

This report documents a test of a temporarily installed hammermill used for the cleanup of recovered light ferrous concentrate removed from municipal refuse at the New Orleans Resource Recovery Project (Recovery 1). As nonmetallic contaminants are removed to a greater extent, both the market value and the range of uses for this product should increase. This report is intended to provide useful information to designers or operators of facilities which recover ferrous metals from municipal refuse.

Francis T. Mayo
Director
Municipal Environmental
Research Laboratory

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This report details test results and describes the equipment used, test procedures, and methods of sample analysis. Results indicate that the apparatus performs well and produces a marketable product. In addition to measuring contamination, particle size, nuggetization, and density, tests were run to assess hammer wear, energy consumption, performance during surges in feed, and performance with unusually large or dense items augmenting feed material.

This report is submitted in partial fulfillment of Contract No. 68-01-4423 by the National Center for Resource Recovery, Inc., under the sponsorship of the U. S. Environmental Protection Agency. Testing was carried out in May - July of 1979; data analysis and reporting were completed in January 1980.

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ACKNOWLEDGMENTS

The cooperation of Recovery 1, a Waste Management, Inc., company, Mr. Norbert J. Bolda, General Manager, and of the City of New Orleans Department of Sanitation, Mr. Patrick J. Koloski, Director, is gratefully acknowledged. Our thanks also go to Mr. Steve Basarab, Vice President, Metals Recovery Division of Proler International Corporation, for his advice and encouragement. Also contributing to this test were Michael Taylor, Michael Veseley, and Laurel Walters, engineering students from the University of New Orleans, employed by NCRR in New Orleans on a co-op or part-time basis.

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SECTION 1

INTRODUCTION

BACKGROUND

The data and analyses reported here resulted from the temporary installation for test purposes of a shredder to process magnetic concentrate extracted from municipal waste.

Analyses of the light ferrous product output stream at Recovery 1 showed contamination levels averaging 16%, with some grab samples as high as 20%. At the time, only ferrous metal magnetically scalped from trommel underflow (raw refuse screened through 4.75" circular holes) was being extracted. Shortly thereafter, scalping of ferrous metal from shredded trommel overflow was begun; the additional metal made up roughly 50% of the product and was somewhat cleaner. Contamination dropped to 11 to 13%. This product was salable, but at a considerably lower price than had been originally negotiated.

A decision was made to modify an impactor then on site to a hammermill and to run a series of performance tests. Successful tests would lead to a permanent secondary shred and magnetic cleanup system designed to operate in the 3 tph range. The basic tests were run at this range.

The approach to the cleanup problem was suggested by the type of contamination (attached or entrapped material) causing the most difficulty. Loose contaminants (entrained paper, plastics, and other nonmetals) made up only about 10% of the contamination. Attached contaminant (sometimes physically bonded as part of the product, but usually material left in or inserted into cans by the consumer, and material pinched and held by a can during compaction in refuse hauling vehicles) comprised the remainder. The violent impact and tumbling within a small shredder would, it was expected,

(1) tear open cans,

(2) scrape off labels, and

(3) dislodge contaminant.

A subsequent magnetic separation step would then recover the cleaned metal.

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TEST OBJECTIVES

The primary goal of this test of a shredder and belt magnet was the production of material that met the following criteria:

(1) contamination - 4% by weight or less nonmagnetic metal included with product,

(2) particle size - 95% greater than 1", and

(3) density - 21.5 to 26 lb/ft^3 after compaction.

An additional goal was to observe characteristics of the test shredder to determine its suitability as a part of a permanent magnetic concentrate cleanup system. Of interest were hammer wear rate, energy consumption, and general performance when processing surges in feed and tramp metal objects, i.e., unusually large or dense ferrous metal articles.

Summary of Results Related to Objectives

Results of this test of a shredder followed by magnetic separation indicate that the process effectively cleans and densifies ferrous metal without excessive size reduction or nuggetizing. Product contamination is reduced to less than 4%; density is increased to the target figure after compaction; while significant, the propensity of the shredder to nuggetize can be tolerated by the customer; and particle size remains large enough for use by the detinning industry and, subsequently, the copper precipitation processor.

Shredder performance was satisfactory throughout testing. Though the test duration was too brief to determine a long-term hammer wear rate, the wear during the test indicates that excessive, costly maintenance of hammers will not be expected when operating on a production basis. The 50 hp shredder motor was seldom heavily loaded during testing. A surge in feed to 5 tph for more than 10 seconds did, however, cause motor current to exceed the nameplate rating. Unusually large or dense material was processed without undue difficulty. It is anticipated that the shredder will perform reliably when installed as part of the secondary cleanup system for ferrous metal recovery at Recovery 1.

SECTION 2

TEST RESULTS

TEST SUMMARY

Procedure

A series of five kinds of tests was scheduled:

(1) tuning runs - very short (30 seconds to 3 minutes) test runs, after which product quality was assessed and shredder configuration changed if necessary;

(2) standard run - a 30-minute test permitting extended observation of the shredder and generating enough product for detailed analyses; repeated, after improvements to shredder configuration, if necessary;

(3) long-duration run - a 60-minute test yielding data on hammer wear and energy consumption;

(4) surge run - a brief test, including surges in feed up to 5 tph from 10 to 60 seconds in length; and

(5) tramp metal run - a test during which tramp metal objects were inserted into feed material at a controlled rate.

Sample Analysis Plan

For the tuning run, samples of feedstock were analyzed to determine amounts of clean metal and contaminant by the Cleaned Can Catalogue (CCC) method (see Appendix B). Tailings from the post-shred magnetic cleanup were hand-sorted and cleaned to determine amounts of clean metal and contaminant. Product was not analyzed separately other than its total weight. For the product, the relative amounts of clean metal and contaminant were determined by difference, using feedstock and tailings data.

For the 30-minute standard run, grab samples of feedstock were analyzed to determine relative amounts of clean metal and contamination, using the CCC method. Grab samples of product were mixed, then divided into eight subsamples. Four were

combined into two, and these were analyzed for contamination by cleaning per the ASTM proposed Standard Method of Testing Municipal Ferrous Scrap - Magnetic Fraction (see Table A-9 and Section 5, Decontamination); two others were analyzed by heating to determine total combustibles. Using another, larger sample of product, bulk density before and after compaction was measured. Tailings were divided into eight subsamples, four of which were sorted and hand-cleaned to determine amounts of clean metal (and contaminant) (see Table A-7).

The long-duration run provided data on hammer wear and energy consumption. Hammers were weighed prior to all testing, and prior to and after the long-duration run. Current drawn by the shredder motor was recorded throughout the test. In addition, a sample of product was used to check bulk density before and after compaction.

During the surge and tramp metal runs, performance was monitored, but no samples were taken.

TEST RESULTS

Several methods were used to estimate the present contamination of the product. Two were direct approaches as described above. The third involved calculating a materials balance. There are four components to the materials balance. There is one input stream - the feed material - and three output streams:

(1) loss (moisture loss, vapor from spray cans, metal ejected from shredder, etc.),

(2) tailings (rejected by magnet), and

(3) product (picked up by magnet).

Tuning Runs

Materials balances for the first three tuning runs are shown in Table 1. Both mass flow and the percent contamination of each component are shown. There were a total of five tuning runs, but only the first three involved changes in shredder configuration. Therefore, after the third run, detailed data were not taken. Raw data appear in Table A-1.

For Runs 1 and 2, a grate was installed with the breaker plates as close to the hammers as possible. During Run 3 and subsequent runs, the Sector 1 breaker plate was backed away and the grate raised one inch. For both Table 1 and Table 2, mass flows include moisture, and contamination is computed on an as-received basis.

TABLE 1. TUNING RUNS MATERIALS BALANCES

Run		Feed	Loss	Tailings	Product
1	Mass flow (tph)	3.00	0.16	0.15	2.69
	Contamination (%)	12.90	81.70	83.70	5.09
2	Mass flow (tph)	2.94	0.17	0.13	2.62
	Contamination (%)	11.80	85.30	75.50	3.68
3	Mass flow (tph)	2.88	0.14	0.19	2.54
	Contamination (%)	8.99	80.10	43.70	2.27

TABLE 2. STANDARD RUN MATERIALS BALANCE

	Feed	Loss	Tailings	Product
Mass flow (tph)	3.29	0.15	0.26	2.88
Contamination (%)	10.40	80.00	67.00	1.85

Standard Run

A materials balance was constructed using grab samples of the feedstock to determine the amount of magnetic material and the base line contamination (10.4%). The tailings were also sampled and the samples hand-cleaned to determine composition. The nonmagnetic portion was 67%. This information was combined with the loss figures from the tuning runs, i.e., the loss relationship established in these runs was used as an estimator. With this data and the overall weight of the magnet product, the percent contamination of the product was computed at 1.85% (see Table 2).

The two direct methods provided different answers (Table 3) to the product percent contamination question. The ASTM wet wash method showed an average contamination for the two samples of 3.10%. The combustion method produced an estimate of 1.76%, averaging two samples. It is felt that the combustion test is biased low, as difficulty was experienced in controlling the temperature of the oven; as a result, it is possible that some of the combustibles were not burnt. The materials balance approach suffers from estimating problems, including such inaccuracy as is associated with the CCC method used to establish the percent contamination from the samples taken of the feed. The wet wash method is believed to be the most accurate

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TABLE 3. CONTAMINATION OF PRODUCT

Approach		Contamination
Materials balance estimation		1.85%
ASTM Wet Wash Method		
Subsample	3.69%	
Subsample	2.50%	
Average		3.10%
Combustion		
Subsample	1.92%	
Subsample	1.60%	
Average		1.76%

and, the reader will note, produced the highest contamination figure. Nevertheless, even this estimate, 3.10%, is below the 4% criterion set for the test.

Long-Duration, Surge, and Tramp-Metal Runs

Contamination of feed and product was not assessed during these runs, hence a detailed materials balance was not derived. Of interest, however, is the mass flow rate of unusually large or dense objects in the feed. These could potentially damage the shredder. The contemplated permanent ferrous metals cleanup system for Recovery 1 includes an air knife separator, which is expected to separate out the heavy ferrous prior to the hammermill. For this test, these objects were removed by hand-picking. During the tramp metal runs, they were re-introduced by hand-feeding them to the shredder at the measured rate. Data on each of the runs are shown in Table 4.

The feed rate of large objects used in the large tramp run is much higher than should be encountered in practice at Recovery 1. Based on the test, it does not appear that the occasional large object (such as an 8" x 8" fragment of sheet steel) will cause difficulty.

Recovery Efficiency

Recovery efficiency is defined as the ratio of clean metal in the product to clean metal in the feed, expressed as a percentage. Loss of metal can occur during shredding when a fragment lodges in a crevice in the shredder or is thrown out of the machine. Far greater loss can occur at the follow-up magnet if

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TABLE 4. SHREDDER FEED RATES
(in Tons per Hour)

Test Run	Large Objects	Dense Objects	Total Added/ (Removed)	Feed Before Addition/ (Removal)	Net Feed Rate
Standard	-	-	(0.045)	3.34	3.29
Long-duration	-	-	(0.12)	3.74	3.62
Surge	-	-	-	-	2.4 to 5.0
Large tramp	0.62	-	0.62	2.4	3.02
Dense tramp	-	0.32	0.32	2.4	2.72

magnetic field strength is low. This may have been the case for these tests. A stronger magnet is planned for the permanent installation. Table 5 lists recovery during those test runs for which detailed data are available. For the standard run, recovery efficiency is derived from the materials balance data in Table 2.

TABLE 5. RECOVERY EFFICIENCY

Test Run	Recovery
Tuning run 1	98.0%
" " 2	97.7
" " 3	94.7
Standard	95.9

Bulk Density

A 60,000-lb minimum weight is specified for railcars shipped from Recovery 1. Since the typical hopper car has a nominal volume of 2,960 ft^3, a bulk density greater than 20.3 lb/ft^3 is needed to insure that at least the minimum weight is transported.

At Recovery 1, a compactor - a hydraulic cylindrical ram - crushes recovered light ferrous product to increase density prior to railcar loadout. The test objective was to achieve

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bulk densities, after compaction, greater than the 20.3 lb/ft^3 needed to make minimum weight in a 2,960 ft^3 car. For several test runs, bulk density before and after compaction was measured. Table 6 shows these data and indicates that this test objective was met; in several cases, compaction was unnecessary.

TABLE 6. BULK DENSITY OF PRODUCT
(in Cubic Feet)

Test Run	Bulk Density Before Compaction	Bulk Density After Compaction
Tuning run 1	14.9	-
" " 2	16.0	-
" " 3	14.3	-
" " 4	18.3	-
" " 5	18.9	21.6
Standard	20.1	22.8
Long duration, sample 1	20.7	21.3
Long duration, sample 2	20.5	23.6

Particle Size and Shape

Referring to Table 6, higher bulk density might have been achieved by changing the size or location of the shredder grate or hammers; however, additional nuggetization of the product could have resulted. This is undesirable, as nuggetized cans cannot be as efficiently detinned. The extent of nuggetization and the contamination of nuggetized cans were evaluated during the tuning runs, and the data appear in Tables A-2 and A-3.* An average 38% of the cans were evaluated as nuggetized. This caused concern, and samples of the product from the tuning runs were sent to Recovery 1's customer. There it was determined that this degree and extent of nuggetizing was acceptable. Hopefully, longer runs with hammers subject to more wear will not increase nuggetizing.

It is desirable to minimize the amount of the product less than 1", as small particles are not as useful to the customer as those in the 1" to 4" size range. Smaller particles increase

*A precise definition of nuggetization was not available for this test. The somewhat subjective definition used here is explained under "sorting" in Section 5.

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bulk density, however. Therefore, there is a trade-off. The test objective of 5% (by weight) less than 1" proved to be impossible to meet, as the magnetic concentrate, i.e., the feed material, was typically 5% to 10% less than 1". The objective was modified to read: less than 5% of the product shall have been shredded to under 1" particle size. Such material was readily identifiable in the product as shards and fragments of metal (see Table 7).

TABLE 7. TEST PRODUCT PARTICLE SIZE DISTRIBUTION

	Sample 1			Sample 2		
Size Range	Percent in Feedstock	Percent Caused by Shredder	Total Percent	Percent in Feedstock	Percent Caused by Shredder	Total Percent
+4"	-	-	0	-	-	0
-4" +2"	-	-	34.3	-	-	30.90
-2" +1"	-	-	55.6	-	-	51.40
-1" +1/2"	4.83	2.27	7.10	9.20	2.81	12.01
-1/2" +1/4"	1.03	0.46	1.50	2.85	0.55	3.39
-1/4"	-	-	1.53	-	-	2.28
Total	5.86	2.73	100	12.05	3.36	100.00

Shredder Performance

Hammer Wear--

During the initial tuning runs and the standard run, a hammer wear rate of 0.25 lb/ton of magnetic concentrate passed was observed. During this period, just under two tons of material were processed. This is a rather rapid wear rate and would indicate that 20% of the hammers (by weight) could be lost in a week's processing (26 tph of magnetic concentrate, 6 days a week). The initial weight of the set of hammers was 206.4 lbs. However, the wear rate decreased rather significantly during the long-duration test when four additional tons of ferrous concentrate were shredded. The overall rate for the six tons dropped to 0.06 lb/ton, which would indicate a weekly wear of 4.5%. Work hardening of hammers and of hammer hard-facing may have been responsible for the reduction in wear rate as processing continued. Hence, an even further decrease may be anticipated.

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At a wear rate of 4.5%, the 1/2" x 3" working face of the hammer would lose roughly 1/2" of metal (on the average) after a week of processing.

The 0.06 lb/ton wear rate may be compared with a 0.003 lb/ton wear rate for intermediate crushing of soft limestone [1] or with a 0.05 - 0.10 lb/ton wear rate for shredding refuse [2].

Energy Consumption, Long-Duration Run--

Current drawn by the shredder motor was monitored throughout the long-duration run. Using power factor data supplied by the motor manufacturer, energy consumption during the run was calculated. In all, 26.79 kw-hr were consumed, and 8,053 lbs of material shredded in 1.11 hours. Specific energy was therefore 6.65 kw-hr/T, or 8.92 hp-hr/T; power consumption 24.1 kw = 32.4 hp.

The Bond Work Index is a convenient parameter for comparing size reduction devices. A larger value implies a greater specific work needed to accomplish a given size reduction. It is the value E_i in the formula

$$E = 10E_i\left[\frac{1}{\sqrt{L_p}} - \frac{1}{\sqrt{L_F}}\right]$$

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where E = specific energy, kw-hr/ton

L_p = product particle size, microns

L_F = feed particle size, microns

Assuming a feed particle size of 80% less than 4", and product particle size of 3" (80% passing, from Table 7), the magnitude of E_i is 1,370 [2].

Performance During Surge and Tramp Metal Runs--

Four surges in feed, at 5 tph, were planned. Surges were to last 10 seconds, 20 seconds, 30 seconds, and 60 seconds. Three runs were attempted. The first (10-second) run was successfully accomplished. However, two attempts to go beyond 10 seconds were terminated when the motor current exceeded the nameplate limit after 15 seconds. The current buildup, although rapid, was steady rather than exhibiting sharp spikes, which indicates a general overload rather than jamming.

In the first tramp metal run, the usual feedstock was augmented with large objects (typically, an 8" x 8" steel fragment). This was done at a very high rate - at least ten times what is expected to be seen in the ferrous concentrate feedstock; motor current rose steadily for 30 seconds until the

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limit was exceeded and the test curtailed by stopping feed to the shredder. Another 30 seconds were required for the shredder to clear. It was concluded that during normal operation the occasional large object can be processed without incident.

In the second tramp metal run, feedstock was augmented with unusually dense objects (e.g., pipe, brake shoes, etc.); these were processed with only a moderate increase in power consumption and no feeding or jamming problems.

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SECTION 3

EQUIPMENT DESCRIPTION

The test apparatus is diagrammed in Figure 1. Components are described in the following paragraphs.

FEED CONVEYOR

Length: 36'

Belt width: 18", with 20° troughing idlers

Width of flat center: 8"

Belt speed: 53 fpm, changed to 102 fpm prior to long-duration run

Angle of inclination: 16°

SHREDDER

Gruendler Model 30-2

16 hammers, manganese steel with hard facing (Figure 2)

Grate, with openings 3" x 7"

Hammer tip speed: 5,540 ft/min

Rotor rpm: 920

Hammer positioning: 4 rows of 4 hammers (Figure 3)

Drive motor: General Electric Type K, NEMA Design B, 50 hp severe-duty motor, rated at 58.5A, 460V 3-phase

Moment of inertia, hammers and rotor: 325.4 lb/ft^2

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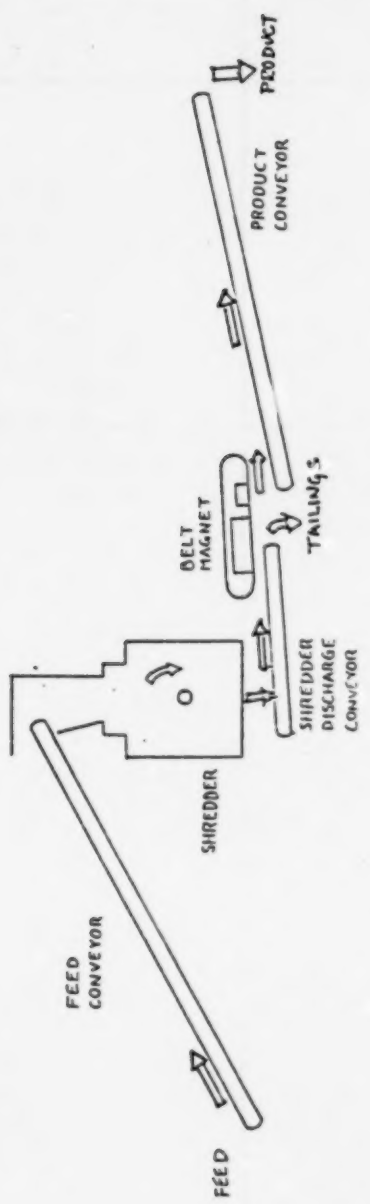

Figure 1. Diagram of test apparatus

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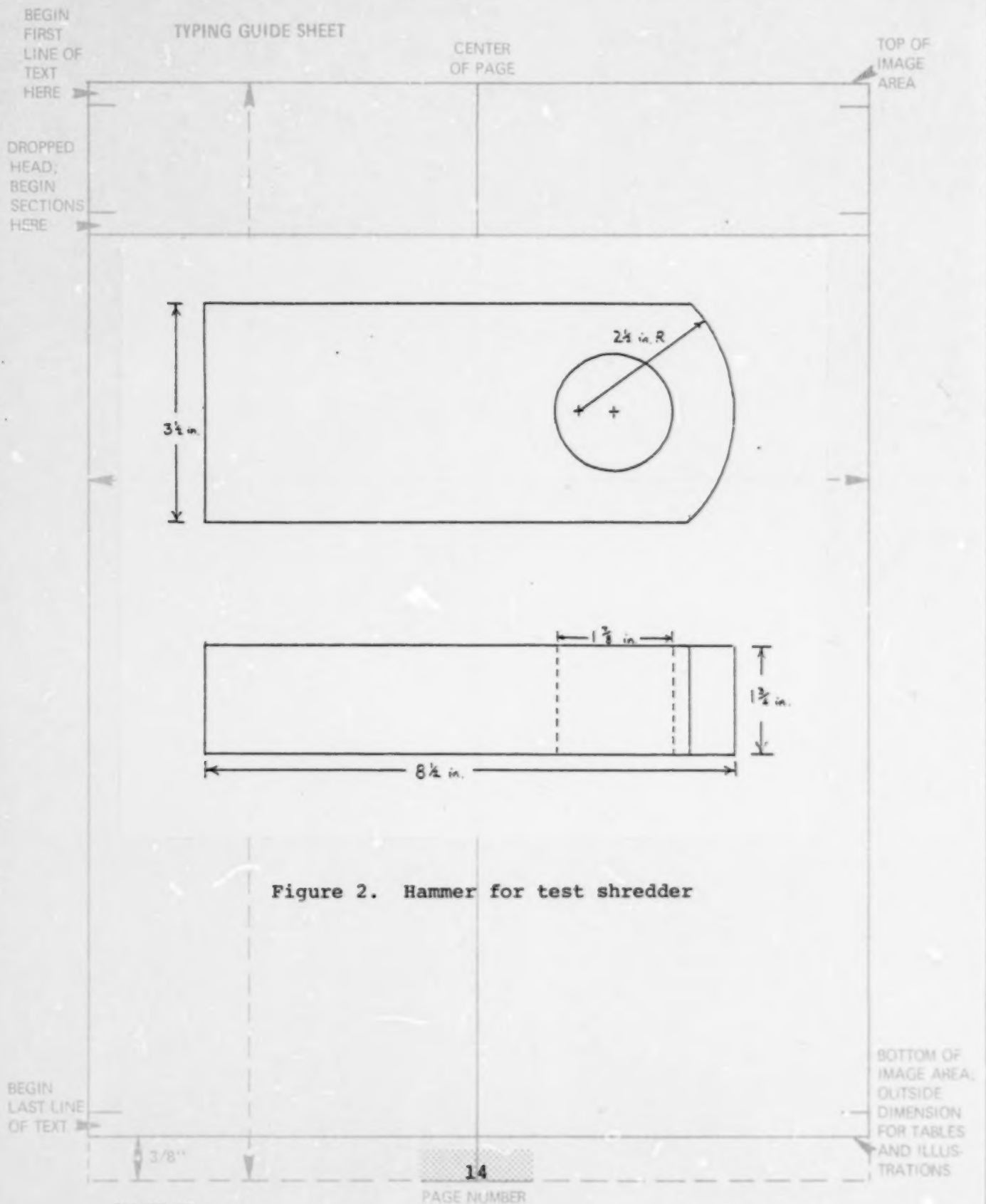

Figure 2. Hammer for test shredder

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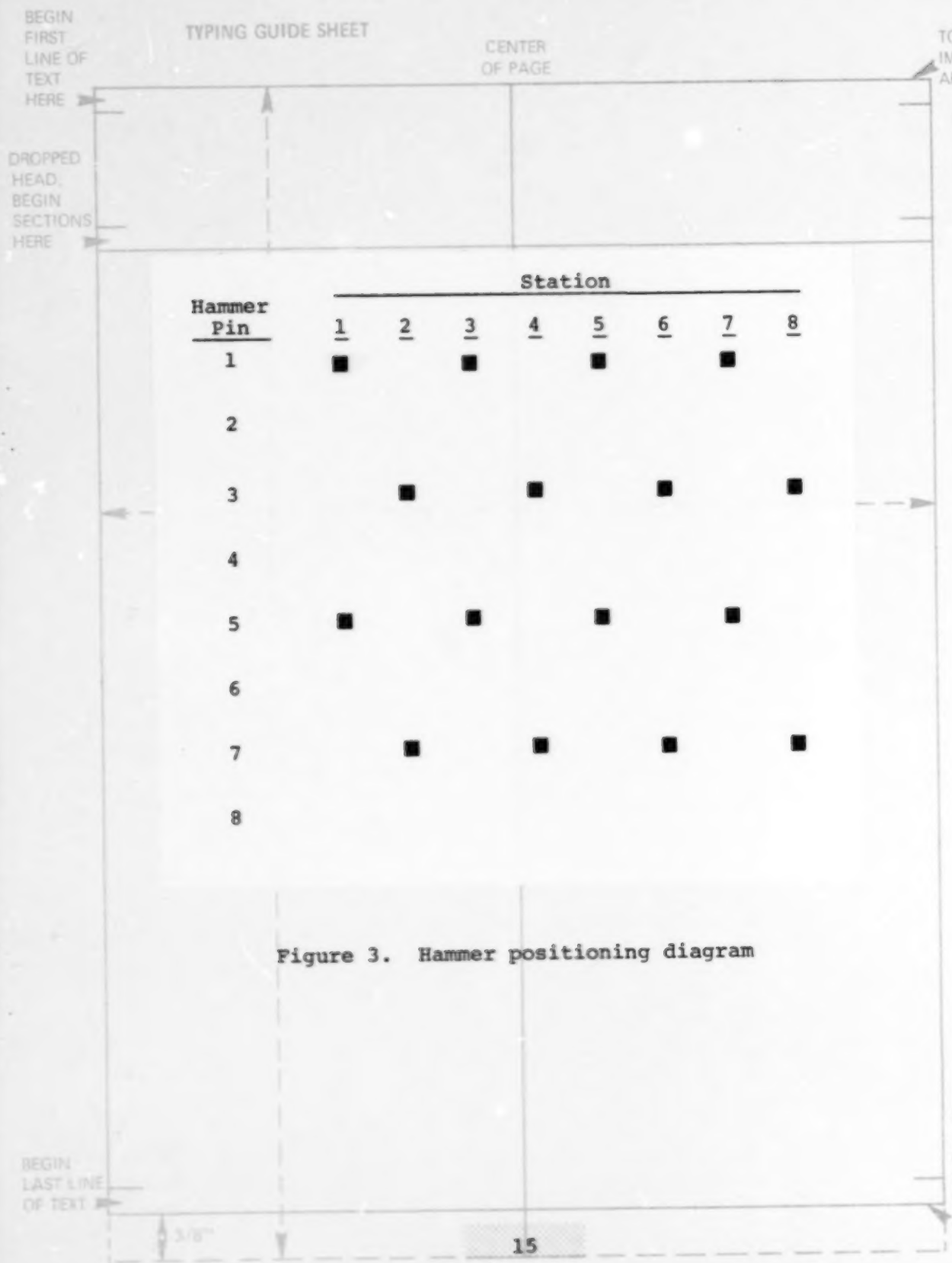

Figure 3. Hammer positioning diagram

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SHREDDER DISCHARGE CONVEYOR

Slider-bed type, length 9' 10"

Belt width: 24" (flat)

Belt speed: 205 fpm

Angle of inclination: 8°

BELT MAGNET

Eriez self-cleaning, permanent magnet type

Belt width: 18"

Belt speed: 450 ft/min

Angle of inclination: 10°

Air gap, magnet to shredder discharge conveyor: 5"

MAGNETIC PRODUCT CONVEYOR

Flat-belt type, cleated, length 24'

Belt width between skirts: 9"

Total belt width: 18"

Cleat width: 5"; cleat spacing: 18"

Belt speed: 135 fpm

Angle of inclination: 13°

SECTION 4

TEST DESCRIPTION

GENERAL

Test objectives are stated in Section 1; procedure is briefly outlined in Section 2. Specifics of the test procedure are given below.

TEST PROCEDURE

Tuning Runs

Preparation of Feedstock--

For Runs 1 and 2, four grab samples of recovered light ferrous material were taken from the product stream immediately prior to compaction and loadout at Recovery 1. Identifiable cans were selected from these grab samples and their contamination analyzed, using the CCC method described in Appendix B. Approximately 50 lb of test feed material were prepared each time. This was loaded onto the feed conveyor to provide 30 sec of run time at 3 tph.

Run 3 feedstock was prepared in the same way, except that a pile of uncompacted light ferrous material which had been collected for other purposes was the source of identifiable cans.

Run 4 feedstock consisted of cans drawn from the same pile, but contamination was not measured.

Run 5 feedstock was a mixture of cans and other light ferrous material (bottlecaps, jar lids, etc.) from the same pile. Contamination was not measured.

For all five runs, feed material was pre-sorted to eliminate tramp metal (large or dense) objects.

Duration of Tests--

For Runs 1, 2, and 3, the loaded feed conveyor provided 30 sec of feed material to the shredder. For Runs 4 and 5, the system was manually fed for 1 and 3 min, respectively.

Sampling--

For Runs 1, 2, and 3, samples consisted of all material in each stream. Feedstock was analyzed prior to running; both the product (magnetics) and the tailings (nonmagnetics) from the belt magnet were collected. For Runs 4 and 5, only the product was saved and considered a sample. Run 5 product was further processed through the can compactor on site.

Monitoring and Control--

Runs 1 and 2 were monitored by observation only. The feed conveyor was long enough to hold a full 30 sec charge of material; hence it was preloaded to assure good control of feed rate. In Run 3, the feed conveyor was also preloaded, and shredder motor current was monitored. Current was also monitored in Run 4, but the longer test time (1 min) prevented preloading of all feed. Some feed material was hand-loaded onto the feed conveyor during the run, with burden depth controlled visually. All feed material was hand-loaded during Run 5. Metering of the feed to maintain steady flow was done manually during loading.

Data from current monitoring of Runs 3 and 4 are listed in Table A-4. These data provided a first indication of motor current during shredding.

Standard Run

One standard run of 30-min duration was performed. The purpose was to obtain data on materials balance, or cleanup of feedstock, and to observe continuous shredder operation during an interval considerably longer than the preceding (3-min) test.

Preparation of Feedstock--

On the day prior to the test, a 14 yd^3-capacity dump truck was used to collect approximately 2 tons of feedstock. The truck was parked in place of a railcar beneath the light ferrous product compactor. The compactor door was held open so that the compactor ram acted merely to push metal out of the compactor, not to compress it.

As feedstock was collected, a total of six 2 ft^3 grab samples were taken (see Sampling, below) and later analyzed (see Table A-6). The truck was weighed before and after filling.

Prior to testing, a known weight of feed material was spread on the feed conveyor so as to deliver 3 tph to the shredder. This was done as a guide for the workers manually loading feedstock onto the feed conveyor.

During testing, tramp metal was removed from the feed conveyor.

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Duration--
The standard run lasted 30 min. There were no interruptions.

Sampling--

Feedstock--A pair of 2 ft^3 grab samples of feedstock were taken at the beginning, middle, and end of the dump truck fill time (approximately 3-1/2 hr), for a total of six samples.

Tramp Metal--During the test, all tramp metal (unusually large or dense) objects were removed from the feed conveyor and reserved. These were later weighed and the weight deducted from the weight removed from the dump truck during testing, to obtain actual weight fed to the shredder.

Tailings--All material rejected by the belt magnet was reserved; later, it was divided by coning and quartering to form eight subsamples, of which four were analyzed (see Table A-7).

Product--At five-minute intervals during the test, 30 sec grab samples of product were taken. These were later mixed and divided by coning and quartering to obtain eight subsamples. These were analyzed for contamination by nonmetals, and for particle size, by various methods (see Section 5, Sample Analyses). Also, between grab samples, four 7 ft^3 fiber drums were filled with product to provide approximately one cubic yard of material for bulk density measurement.

Monitoring and Control--
Shredder motor current was monitored and the shredder feed visually checked during the test to maintain uniform feed rate. Mass flow rates calculated from the six product grab samples (see Table A-8) indicate a variation in flow rate of ±18% about the mean. Shredder motor current, recorded every 5 sec, varied from a minimum of 25A to a maximum of 41A. The mean current reading was 33.8A, with a standard deviation of 1.83A.

Long-Duration Run

The long-duration run, approximately 1 hr in length, was intended to provide a measure of hammer wear. However, during the run, hammer wear was actually too small to be measured reliably. Examination of the hammers shows only nicks and polishing, not significant wear. The run therefore provided an upper limit on hammer wear which is useful in estimating maintenance cost. Actual wear rate will only be measurable after more hours of processing.

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A secondary purpose of the long-duration run was to provide a sizable quantity of product for bulk density measurements before and after compaction. The compaction of samples was done as follows:

(1) Weight and volume of sample were measured.

(2) The compactor hopper was purged of all material.

(3) The sample was manually raised to the compactor hopper, about 15 ft above ground level, using a container suspended from a rope.

(4) The compactor was run through two operating cycles to ensure that all material was processed. Hydraulic pressure was monitored as a check on machine performance. Material was discharged into either a front-end loader bucket or down a ramp into a rectangular container.

(5) If discharged into the front-end loader, the compacted sample was transferred to a number of fiber drums.

(6) Weight and volume of sample were again measured.

The above procedure was followed after both the standard and long-duration runs.

Preparation of Feedstock--

On the day prior to the test run, two 14 yd^3-capacity dump trucks were used to collect feedstock from the can compactor, as in the standard run. Approximately 4.3 tons were collected in a 4-1/2-hour period.

During testing, tramp metal was removed from the feed conveyor by hand.

Duration--

Each truckload was run separately with an interruption in feed as trucks were changed. Total feed time was 66 min 37 sec (see Table A-12).

Sampling--

Hammers--Hammers were weighed prior to this run. They were reweighed after the run was completed.

Tailings--As the first truckload was processed, tailings were collected. These were later weighed.

Product--At approximate 10-min intervals, a sample of product was collected by filling a 7 ft^3 fiber drum. Seven such

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drums were filled during the test. This material was used to evaluate product bulk density before and after compaction.

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Monitoring and Control--
Shredder motor current was monitored and the shredder feed visually checked, as in the standard run, to maintain uniform feed rate. Average feed rate for the run was 3.62 tph.

Surge Runs

Four surges in feed to 5 tph from a background of 3 tph were planned, with durations of 10, 20, 30, and 60 seconds. During the 20-sec and 30-sec runs, the shredder motor current became excessive after 15 seconds. The 60-sec run was therefore dropped.

The tramp metal runs were performed immediately after the surge runs, without an intermediate weighing of the feed material dump truck. Consequently, the background feed rate is known only as an average inclusive of all surge and tramp metal runs. It was 2.4 tph.

Preparation of Feedstock--
On the day prior to the test runs, two 14 yd^3-capacity dump trucks were used to collect feedstock from the can compactor, as in the standard run. Approximately 4.2 tons were collected. From one truck, twelve 30-gallon plastic sacks were each filled with 27.8 lb of tramp-free material. Each surge to 5 tph was to be obtained by feeding one sackful per 10 seconds. The background feed of 3 tph would be controlled by hand-metering material onto the feed conveyor from the back of the dump truck, as for the standard and long-duration runs.

During testing, tramp metal was removed from the feed conveyor by hand.

Duration--
Surges, beginning with the 10-second surge, were spaced approximately 3 min apart. After the 20-second surge (and resultant overload of the shredder motor), additional time was needed for the shredder to clear.

Sampling--
No samples were taken.

Monitoring and Control--
Shredder motor current was monitored and the feed visually checked.

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Tramp Metal Runs

In a ferrous metal cleanup system, a small shredder of the type under test might sustain damage if presented with one or several unusually large or dense iron or steel objects. The tramp metal runs were done to permit observation of the shredder under such strenuous conditions.

Preparation of Feedstock--

Tramp metal objects picked from the feed during the previous test runs were sorted into two categories. A typical large object was a piece of sheet steel, 8" x 8" in size, from the shredding of a household appliance. A typical dense object was a piece of pipe 2" in diameter and 12" long, or an automotive brake shoe. Each category was weighed prior to testing.

During testing, tramp metal occurring in the background feed material was removed from the feed conveyor by hand.

Duration--

Including time to reach steady state with a background level of feed, each tramp metal run lasted less than 10 min. Feed of large objects required 75 sec and was curtailed by shredder motor overload. Feed of dense objects required 3 min 35 sec; all dense objects were fed.

Sampling--

No samples were taken. Product was examined for large unshredded objects or other unusual material. None were noted.

Monitoring and Control--

Both large and dense objects were placed one at a time on the feed conveyor. Approximately 5 to 10 seconds elapsed between the placement of individual objects. For the background material, shredder motor current was monitored and the feed visually checked. Average background for combined surge and tramp metal runs was 2.4 tph.

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SECTION 5

DESCRIPTION OF SAMPLE ANALYSES

STANDARD PROCEDURES

In the discussion of analysis procedure, several standard or often-repeated procedures will be referenced by name only. These are:

(1) Coning and quartering - per ASTM method C702, Reducing Field Samples of Aggregate to Testing Size.

(2) Cleaned Can Catalogue (CCC) method of contamination analysis - described in Appendix B.

(3) Bulk density measurement. Material is placed in the specified container, in several (3 to 6) increments. After each increment, the container is agitated by rocking several times, first side to side, then front to back, so that material settles. When the container is filled or material is exhausted, the container is agitated until no more settling is observed.

DRYING

Product Subsamples 1 through 6 from the standard run were dried in the drying oven at 103°C for 24 hr (see Table A-9).

SAMPLE DIVISION

The six grab samples of standard run product, taken at approximately equal intervals during the run, were poured together and mixed by hand, using shovels, on a concrete floor protected with a polyethylene sheet. The product was then coned and quartered a total of eight times, with half of the material held in reserve and the remaining half divided into eight subsamples of approximately 1 ft^3 each (see Table A-8). Two of these subsamples, Nos. 5 and 6, were later divided in half for ease of handling.

The standard run tailings were divided in a similar manner, with half of the material (Subsamples 3 and 4) held in reserve, and the remaining half divided into four subsamples (1A, 1B, 2A, 2B) approximately 1 ft^3 each.

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SORTING

For the first four tuning runs, product was sorted by hand into three categories: (1) nuggetized, (2) open, and (3) not sure. Nuggetized product was defined as those cans so severely crumpled or balled tnat, in the sorter's judgment, there was a significant loss of surface area which would make it difficult for caustic solution to accomplish the detinning process. Open product was defined as the complement, i.e., cans which could be easily detinned. The subjective nature of this sorting necessitated a third category to contain cans which were not clearly nuggetized or open. To ensure a degree of uniformity, the same person supervised all such sorting. See Table A-2 for results.

Tailings from the first three tuning runs were hand-sorted to remove magnetic objects from nonmagnetic material. Table A-1 shows results.

Feed material during the standard, long-duration, surge, and tramp metal runs was sorted in that uncommonly large (approximately >6") or dense objects were removed from the feed conveyor. Material removed in this manner from the feed for the standard and long-duration runs was separated into the two categories, large objects and dense objects. These were metered into the feed of the tramp metal runs (see Section 4, Tramp Metal Runs). Tables A-5, A-12, and A-15 contain relevant data.

Tailings subsamples from the standard run were hand-sorted to remove magnetic objects from nonmagnetic material. The permanent belt magnet used to clean up shredded material during testing was also used in this sorting operation. With the belt drive shut off, tailings containing magnetics were held against the magnet and allowed to drop. Magnetics stuck to the belt and were then hand-picked (see Table A-7).

BULK DENSITY

The procedure for measurement of bulk density is described under Standard Procedures, Page 23. Table 8 gives the container used for each measurement and the relevant data table(s). All drums were weighed, full and empty, on the platform balance. The cart was weighed on the wheeled platform scale.

SCREENING

After drying, combined product Subsamples 1 and 2 were screened in several batches on the test sieve. Each batch was loaded onto the sieve and screened for 10 min. Material reporting to each size fraction was weighed on the triple-beam

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TABLE 8. BULK DENSITY MEASUREMENTS

Test Run	Material	Container	Data Table
T1	Product	2 ft^3 drum	A-2
T2	Product	2 ft^3 drum	A-2
T3	Product	2 ft^3 drum	A-2
T4	Product	2 ft^3 drum	A-2
T5	Product	Rectangular cart	A-2
Std	Feed	2 ft^3 drum	A-6
Std	Tailings	7 ft^3 drum	A-7
Std	Product	4 ft^3 drum, 1 ft^3 drum	A-8
Std	Product compaction sample	7 ft^3 drums	A-11
Long	Product	7 ft^3 drums	A-14

balance or (if weight exceeded 2.61 kg) on the platform balance. Combined Subsamples 3 and 4 were screened identically. Results appear in Table A-10.

DECONTAMINATION

The CCC method of contamination analysis permits the analysis of a sample of steel cans without removal of contaminant. For Tuning Runs 1 - 3, recognizable cans were used as feedstock, and contamination was determined by this method. This, of course, biased the feed to contain only recognizable cans, eliminating smaller objects and non-container materials (e.g., children's toys, kitchen utensils). However, the vast majority of recovered ferrous objects are cans, so the bias was felt to be unimportant for tuning of the shredder.

Magnetics found in the tailings from Tuning Runs 1-3 were analyzed for contamination using the CCC method. When necessary, cans were heated to 750°F for one hour, shaken to dislodge ash, and weighed on the triple-beam balance to obtain a clean metal weight. Data appear in Table A-1.

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There was concern that the nuggetized portion of product contained entrapped contaminant, not visible by inspection. Cleaning nuggetized cans by washing the scraping was a physical impossibility. Therefore, to assess contamination of nuggetized cans, several batches from the product of Tuning Run 4 were heated to 750°F for one hour, shaken to dislodge ash, and weighed on the triple-beam balance to obtain a clean metal weight. These data are summarized in Table A-3.

For the standard run, six grab samples of feedstock were analyzed for contamination. After obtaining an initial weight, the sample was sorted into recognizable cans or other objects. The CCC method was employed to find the contamination of recognizable cans. Other objects were manually cleaned; when necessary, they were heated to 750°F for one hour to oxidize organics. Cleaned metal weights for these other objects were found using the triple-beam balance.

Product from the standard run was analyzed for contamination by two methods. For Subsamples 1 - 4, an attempt was made to follow the ASTM proposed Standard Method of Testing Municipal Ferrous Scrap - Magnetic Fraction (for the Detinning Industry), in which the sample is treated as follows:

(1) Material is weighed, then manually separated, using a hand magnet, into magnetic and nonmagnetic fractions.

(2) The magnetic fraction is washed for two minutes in a galvanized 20-gallon tub using 180°F (82°C) water.

(3) Hot water is quickly drained, and the sample is rinsed for one minute.

(4) Sample is drained, air dried for 24 hours, and weighed.

The above procedure was used with the following exceptions:

(1) During manual separation, an effort was made to dislodge contaminant attached to metal, especially cardboard can bodies.

(2) Sample was oven dried at 103°C for 24 hours, after washing.

Subsamples 5 and 6 were analyzed by a loss-on-combustion technique. Preliminary work by NCRR staff had established that most contaminants of light ferrous product, except some plastics, are oxidized to ash after 24 hours at 550°F. Accordingly, Subsamples 5 and 6 were weighed on the platform balance, then each divided in half for ease of handling (no special sample division was used), and plastics were manually removed. The subsamples

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were placed in the bench oven for 24 hours at maximum temperature, which was known to approach 550°F. Upon cooling, subsamples were shaken for several minutes in the test sieve to dislodge ash. The ash was scalped with a hand magnet, and magnetic fragments found in the ash were returned to their respective subsamples. Final weights of subsamples were obtained on the platform balance. Data appear in Table A-9.

HAMMER WEAR

Hammer weights were obtained by the following method. First, hammers were scraped clean, washed in hot, soapy water with a scrub brush, then wiped and air dried. (This was not necessary for the first weighing, as hammers were new and clean.) Then each hammer was individually weighed on the platform balance. Weight data appear in Table A-13.

RECORDING AMMETER DATA REDUCTION

Shredder motor current was mechanically recorded every 5 sec during several test runs. To measure power consumption using these data, for the long-duration run, the following procedure was used:

(1) From each current measurement, a power factor value was interpolated using data supplied by the motor manufacturer.

(2) Work done during each 5-sec interval was computed from the equation

$$W = \sqrt{3}\, EItPF$$

where W = work, in joules
E = 500V (measured)
I = current, amperes
t = 5 sec
PF = power factor

Note that the power supply was nominally 480V 3-phase.

(3) Work done was summed over the entire test interval.

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SECTION 6

DISCUSSION

RECOVERY 1 FERROUS SYSTEM REDESIGN

Because of the need to produce a cleaner light ferrous product, the ferrous metals recovery system at Recovery 1 has been redesigned to include the shredder which is the subject of this report. Additional equipment has been included in the redesign: principally, an armored belt magnet (to separate metal from dislodged contaminant) and an air knife, which will protect the shredder from dense objects.

Maintenance costs for the redesign are not yet known, as one of the major components - hammer wear - has not yet been definitely quantified. Of course, a net increase in revenue is expected from operation of the redesigned system, but it may be small, especially at the outset. Because the quality of refuse and the market value of ferrous metal are to a degree site-specific, other recovery facilities should consider secondary processing of recovered ferrous metal only after careful economic analysis.

IMPROVEMENTS IN SHREDDER DESIGN

Several possible improvements in shredder design came to light during testing. Hardfacing should extend farther up the hammer, to within an inch of the pivot hole. Hammers might tear cans open more readily if hammer faces were beveled; cans would be struck by an edge rather than a face, and impact force per unit of contact area would increase.

Other arrangements of hammers about the shredder rotor may prove to be more effective. Finally, shearing action within the shredder might improve if the breaker plates were modified to contain "teeth" (at present, they are flat plate).

CONSIDERATIONS REGARDING TESTING

There were several unexpected difficulties encountered during testing. Measurement of contamination of feedstock for the standard run should have been more precise; ten grab samples, rather than six, would have improved precision appreciably.

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From the six grab samples taken, total contamination ranged between 6.5% and 13.2%, averaging 10.2%. Statistical analysis reveals that the true mean (of a large number of grab samples) might lie anywhere between 8.4% and 12.0%, with 90% confidence.

Even from the limited number of samples taken, it is clear that feedstock contamination was below the usual 11 - 16% range. Results from the tuning runs suggest that more heavily contaminated feedstock will have a greater proportion of contaminant removed during shredding.

In the total-combustibles analysis of product from the standard run, the bench oven did not consistently attain 550°F. Testing of the shredder is planned after it is installed as part of the ferrous metals recovery system redesign. For such testing, the proposed ASTM "hot-water wash" method of contamination analysis will be used.

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REFERENCES

1. Taggart, A. F., Handbook of Mineral Dressing, J. Wiley & Sons, New York, 1964, p. 4-87.

2. Trezek, George J., Significance of Size Reduction in Solid Waste Management, Environmental Protection Technology Series, Report No. EPA-600/2-77-131, Springfield, Virginia: National Technical Information Service, July 1977, pp. 100, 114.

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APPENDIX A

TEST DATA AND RESULTS

TABLE A-1. TUNING RUNS - MATERIALS BALANCE

		Run 1 5-16-79	Run 2 5-18-79	Run 3 5-29-79	Run 4 5-31-79	Run 5 6-11-79
Run Duration	(sec)	27.8	30.9	27.4	60.0	180
Configuration		All breaker plates in; grate installed		Breaker plate I out; grate raised 1"		Same as 3, 4
Feed Rate	(tph)	3.00	2.94	2.88	2.78	2.93
Motor Current	(A)		32 (peak)	37 (peak)	35.1 (avg)	
Feed Material						
Clean Metal	(g)	18,280	20,164	18,079		
Contaminant	(g)	2,710	2,703	1,785		
(Total)	(g)	(20,990)	(22,867)	(19,864)	(42,024)	(132,930)
Product (Magnetics)						
Clean Metal	(g)	17,914	19,707	17,124		
Contaminant	(g)	961	753	397		
(Total)	(g)	(18,875)	(20,460)	(17,521)	(38,200)	(120,970)
Tailings (Non-magnetics)						
Clean Metal	(g)	166	257	755		
Contaminant	(g)	854	793	585		
(Total)	(g)	(1,020)	(1,050)	(1,340)		
Loss						
Clean Metal	(g)	200 (est)	200 (est)	200 (est)		
Contaminant	(g)	895	1,157	803		
(Total)	(g)	(1,095)	(1,357)	(1,003)		

TABLE A-2. TUNING RUNS - PRODUCT DENSITY

	Run 1 5-16-79	Run 2 5-18-79	Run 3 5-29-79	Run 4 5-31-79	Run 5 Before Compaction 6-11-79	Run 5 After Compaction 6-11-79
Mixed product*						
Weight (lb)	36.10	39.18	29.70	84.23	266.75	260.75
Volume (ft^3)	2.43**	2.45**	2.07**	4.61**	14.12***	12.07***
Bulk density (lb/ft^3)	14.9	16.0	14.3	18.3	18.9	21.6
Analysis date	5-30-79	5-30-79	5-30-79	5-31-79	6-11-79	6-11-79
Nuggetized portion						
Weight (lb)	11.14	17.73	12.37	41.23	Analysis	Analysis
Volume (ft^3)	0.419**	0.654**	0.504**	1.74**	not	not
Bulk density (lb/ft^3)	26.6	27.1	24.5	23.7	completed	completed
Weight of total* (lb)	39.45	41.53	35.73	84.23		
% Nuggetized	28.2%	42.7%	34.6%	49.0%		
Analysis date	5-21-79	5-21-79	5-30-79	5-31-79		

*May be less than total in Table A-1.

**Measured in cylindrical drum.

***Measured in rectangular container, 3' x 4.5' x 2' deep.

TABLE A-3. TUNING RUN 4 - CONTAMINATION OF NUGGETIZED PRODUCT

Sample No.	Weight Before Heating (g)	Weight After Heating (g)	Weight of Combustibles (g)	Percent Contamination
1	551.96	544.04	7.92	1.43
2	695.28	684.07	11.21	1.61
3	210.12	207.91	2.21	1.05
4	237.22	234.59	2.63	1.11
5	313.63	308.07	5.56	1.77
6	381.31	376.21	5.10	1.34

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TABLE A-4. TUNING RUNS 3 AND 4 - SHREDDER MOTOR CURRENT

Elapsed Time (Sec)	Run 3 Motor Current (A)	Run 4 Motor Current (A)
-10	22	22
-5	22	22
0	22	22
5	23	26
10	26	29
15	28	36
20	30	32
25	33	35
30	38	37
35	35	33
40	26	36
45	23	35
50	22	34
55	22	37
60		36
65		31
70		29
75		30
80		29
85		26
90		25
95		22
100		22

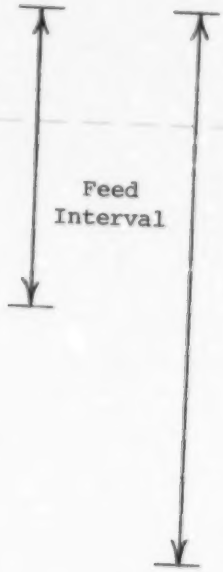

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TABLE A-5. STANDARD RUN - MATERIAL BALANCE

Date	June 14, 1979
Run duration (min:sec)	30:00
Motor current (A)	33.8 (avg)
Feedstock weight (lb)	3,335
Tramp metal picked (lb)	45
Net feed weight (lb)	3,290
Feed rate (tph)	3.29
Tailings weight (lb)	261

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TABLE A-6. STANDARD RUN - FEESTOCK GRAB SAMPLE COMPOSITION

	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5	Sample No. 6	Total
Sample volume (ft^3)	2	2	2	2	2	2	12
Sample weight (lb)	14.4	19.1	22.9	21.1	21.1	24.6	123.2
Sample bulk density (lb/ft^3)	7.2	9.6	11.4	10.5	10.5	12.3	10.3
Light ferrous							
Clean metal							
Weight (g)	5,932	7,370	8,066	7,460	8,119	8,434	45,381
(% of total)	(90.6)	(85.0)	(77.8)	(86.6)	(85.0)	(78.9)	(83.4)
Contaminant							
Weight (g)	398	810	894	940	901	736	4,679
(% of total)	(6.08)	(9.34)	(8.62)	(10.91)	(9.43)	(6.89)	(8.59)
Heavy ferrous							
Clean metal							
Weight (g)	191	399	1,342	191	421	842	3,386
(% of total)	(2.91)	(4.61)	(12.94)	(2.22)	(4.40)	(7.88)	(6.22)
Contaminant							
Weight (g)	15.1	46.0	20.8	2.5	63.1	576.9	724.4
(% of total)	(0.23)	(0.53)	(0.20)	(0.03)	(0.66)	(5.40)	(1.33)
Loose contaminant							
Weight (g)	12.1	42.6	47.9	23.6	53.0	96.8	276.0
(% of total)	(0.18)	(0.49)	(0.46)	(0.27)	(0.55)	(0.91)	(0.51)
Deleted heavy ferrous (g)*	0	0	0	948	0	450	1,398

*Heavy ferrous objects which would have been picked from feed conveyor during test.

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TABLE A-7. STANDARD RUN - TAILINGS COMPOSITION

Tailings weight: 260.8 lb
Volume: 10.08 ft^3
Bulk density: 25.9 lb/ft^3

Subsample No.	1	2	3*	4*
Subsample weights** (lb)	62.84	65.38	60.51	69.33
Subsample, Part A				
Magnetic metal (lb)	11.30	12.28		
Attached contaminants (lb)	0.95	1.45		
Loose contaminants (lb)	22.01	20.25		
Subsample, Part B				
Magnetic metal (lb)	8.35	10.39		
Attached contaminants (lb)	1.01	1.04		
Loose contaminants (lb)	19.22	19.97		

*Subsamples 3 & 4 were not analyzed for composition.
**Loss during sample division: 2.7 lb.

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TABLE A-8. STANDARD RUN - PRODUCT SAMPLES AND SUBSAMPLES

	Grab Sample No.						
	1	2	3	4	5	6	Total
Sample start time (0:00 = test start)	5:00	10:00	15:00	20:00	25:00	28:30	
Sample end time	5:18	10:30	15:30	20:30	25:30	29:00	
Sample weight (lb)	26.12	53.53	38.96	42.00	52.16	55.40	268.17
Sample volume (ft^3)	1.25	2.35	1.88	2.06	2.55	2.46	12.55
Sample bulk density (lb/ft^3)	20.9	22.8	20.7	20.4	20.5	22.6	21.4

	Subsample No.								
	1	2	3	4	5	6	7	8	Total
Sample weight (lb)	16.32	17.13	16.93	15.74	16.32	16.10	16.07	16.89	131.50
Sample volume (ft^3)	0.809	0.766	0.757	0.728	0.919	0.931	0.872	0.845	6.627
Sample bulk density (lb/ft^3)	20.2	22.4	22.4	21.6	17.8	17.3	18.4	20.0	19.8

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TABLE A-9. STANDARD RUN-PRODUCT SUBSAMPLE CONTAMINATION ANALYSES

Modified ASTM Method						
Subsample No.'s			1 & 2			3 & 4
Weight (g)						
Initial			15,170			14,820
After drying (% moisture)			14,960 (1.38)			14,695 (0.84)
After picking (% contamination, dry basis)			14,890 (0.47)			14,585 (0.75)
After washing, drying, and screening			14,694 (1.78)			14,486 (1.42)
After re-picking			14,610 (2.34)			14,449 (1.67)
Loss on Combustion (24 hr, 550°F)						
Subsample	5A	5B	5	6A	6B	6
Weight (g)						
Initial			7,400			7,300
After drying (% moisture)	3,866	3,530	7,396 (0.05)	3,654	3,604	7,258 (0.58)
After combustion and ash removal (% contamination, dry basis)	3,817	3,441	7,258 (1.87)	3,612	3,571	7,183 (1.03)
Oven temperature (°F)	550	450		550	525	

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TABLE A-10. STANDARD RUN - PRODUCT PARTICLE SIZE DISTRIBUTION

Subsample Nos.	1 & 2	3 & 4
Particle size	Weight (g)	Weight (g)
-4"	0.0	0.0
-4" +2"	5,037.2	4,479.0
-2" +1"	8,168.6	7,444.0
-1" +1/2" (unshredded)	710.4	1,332.6
-1" +1/2" (shredded)	333.5	407.6
-1/2" +1/4" (unshredded)	151.7	412.4
-1/2" +1/4" (shredded)	68.1	79.2
-1/4"	224.3	330.7
TOTAL	14,693.8	14,485.5

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TABLE A-11. STANDARD RUN - COMPACTION OF PRODUCT

	Container No.				
	1	2	3	4	Total
Before Compaction					
Weight (lb)	141.9	140.7	171.3	154.4	608.3
Volume (ft^3)	7.08	7.03	8.05	8.05	30.21
Bulk density (lb/ft^3)	20.0	20.0	21.3	19.2	20.1
After Compaction					
Weight (lb)					600.9
Volume (ft^3)					26.40
Bulk density (lb/ft^3)					22.8

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TABLE A-12. LONG-DURATION RUN - MATERIAL BALANCE

Date: July 18, 1979

	Part 1	Part 2	Total
Run duration (min:sec)	34:35	32:02	66:37
Motor current (A)	25 - 50 avg 35	22 - 50 avg 35	~35
Feedstock weight (lb)	4,327	3,986	8,313
Tramp metal picked (lb)			260
Net feed weight (lb)			8,053
Feed rate (tph)			3.62
Tailings weight (lb)	365		

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TABLE A-13. LONG-DURATION RUN - HAMMER WEIGHTS

Row	Hammer	Station	Initial Weight (kg)	Weight Before Long-Duration Run (kg)	Weight After Long-Duration Run (kg)
I	S4	2	5.96	5.94	5.94
	S3	4	5.89	5.88	5.88
	S2	6	5.78	5.77	5.76
	S1	8	5.77	5.75	5.75
II	R1	1	5.78	5.76	5.76
	R2	3	5.83	5.81	5.82
	R3	5	5.88	5.88	5.88
	G4	7	5.91	5.89	5.89
III	B4	2	5.98	5.96	5.98
	B3	4	5.88	5.88	5.89
	B2	6	5.83	5.81	5.82
	B1	8	5.73	5.72	5.72
IV	G1	1	5.77	5.75	5.76
	G2	3	5.78	5.76	5.77
	G3	5	5.88	5.88	5.88
	R4	7	5.96	5.94	5.96
TOTAL			93.61	93.38	93.46

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TABLE A-14. LONG DURATION RUN - COMPACTION OF PRODUCT

	Container No.					
	1	2	3	4	5	Total
Sample 1						
Before Compaction						
Weight (lb)	152.2	140.4	152.7	152.7	45.7	643.7
Volume (ft^3)	7.25	7.25	7.24	7.13	2.21	31.08
Bulk density (lb/ft^3)	21.0	19.4	21.1	21.4	20.7	20.7
After Compaction						
Weight (lb)	147.5	151.3	150.3	166.3	13.8	629.2
Volume (ft^3)	7.25	7.24	7.13	7.27	0.65	29.54
Bulk density (lb/ft^3)	20.3	20.9	21.1	22.9	21.3	21.3

	Before Compaction	After Compaction
Sample 2		
Weight (lb)	144.3	138.5
Volume (ft^3)	7.04	5.88
Bulk density (lb/ft^3)	20.5	23.6

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TABLE A-15. SURGE AND TRAMP METAL RUNS DATA

Mode	Duration (sec)	Mass Fed (lb)	tph	Maximum Motor Current (A)
Background	215		*	
Surge 1	12	27.8	4.2	42
Background	170		*	
Surge 2	15	41.6	5.0	64
Background	135		*	
Surge 3	15	41.6	5.0	62
Background	145		*	
Tramp 1 (large)	75	25.7	0.62**	56
Background	255		*	
Tramp 2 (dense)	215	38.0	0.32**	53
Background	155			

*Average background feed rate: 2.4 tph.

**Added to background feed, which averaged 2.4 tph.

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APPENDIX B

THE CLEANED CAN CATALOGUE (CCC) METHOD OF CONTAMINATION ANALYSIS FOR LIGHT FERROUS PRODUCT

The "Cleaned Can Catalogue" procedure was developed at Recovery 1 to permit quick and reliable measurement of the contamination of light ferrous product. Central to the procedure is a list (the Catalogue) of the cleaned weights of ferrous metal food and beverage cans and other containers frequently found in New Orleans refuse. A sample is analyzed as follows:

(1) The sample is taken. Sample volume is typically 2 ft^3.

(2) Depending on the source of the sample, sorting to remove nonferrous or non-light-ferrous items may be needed.

(3) The sample of light ferrous, including attached contaminants, is weighed.

(4) The analyst picks through the sample. When a catalogued can is found, it is tallied on a data sheet (Exhibit B-1). If its lid is attached, this is tallied also. The can is then discarded. This continues until no more catalogued cans are found.

(5) Remaining ferrous metal objects (usually a small fraction of the original sample) are manually cleaned and weighed clean.

(6) From the tally sheet, the cleaned weights of the catalogued cans are summed. This is added to the cleaned weight from Step (5) to obtain a cleaned metal weight for the entire sample.

(7) Contaminant is the difference between the weight from Step (3) and the cleaned metal weight from Step (6).

To obtain the cleaned metal weights of cans in the catalogue, several specimen cans for each common shape were manually cleaned and weighed. For a given shape, the arithmetic mean of the individual weights is used as the catalogue weight.

For most shapes, the coefficient of variation of averaged weights is less than 5%; it never exceeds 10%.

Note that the cleaned metal weight includes lacquers and solders applied during can manufacture, rubber or plastic gaskets on threaded jar lids, as well as aluminum tops (minus the pull tabs) on bimetal cans.

As more data are available and new can shapes are marketed, the CCC is periodically updated. Presently, 47 items are listed on the tally sheet; additionally, weights of detachable lids are listed where appropriate. The tally sheet also gives height and diameter of most cans as an aid to the analyst.

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EXHIBIT B-1

CLEANED CAN CATALOGUE (CCC) TALLY SHEET

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Sample _____ Analyzed by _____

Date _____

Can Type	H (")	D (")	Body	Wt (gms)	Top	Wt (gms)
Food, 3-piece						
303, thin	4-3/8	3 ±1/8	_____	56.15	_____	7.80
303, thick	4-3/8	3 ±1/8	_____	63.00	_____	7.68
Buffet	3 ±1/4	2-5/8	_____	37.20	_____	5.60
Tall buffet	4	2-5/8	_____	41.87	_____	5.53
Tuna, large	2-1/4	3-1/4	_____	46.95	_____	
Tuna, medium	1-3/4	3-1/4	_____	34.07	_____	8.5
Tuna, small	1-1/2	2-5/8	_____	25.25	_____	5.15
Evaporated, medium	3-7/8	2-7/8	_____	49.00	_____	
Evaporated, small	2-3/8	2-1/2	_____	26.65	_____	
Enfamil, short	3-7/16	2-5/8	_____	51.40	_____	
Enfamil, tall, rippled	7-5/8	3-1/4	_____	138.17	_____	
Tomato paste	3-3/8	2-1/8	_____	26.97	_____	
Large food	5-1/2	3-3/8	_____	86.98	_____	
Green Giant	3-3/8	3-3/8	_____	59.40	_____	10.2
#2	4-1/2	3-3/8	_____	78.22	_____	9.9
Pineapple	2	3-3/8	_____	42.60	_____	9.4
Frozen juice, 12 oz	4-3/4	4-7/8	_____	43.83	_____	
Yams (#2-1/2)	4-5/8	4	_____	99.98	_____	15.6
#10			_____	277.95	_____	44.23
Punch, 46 oz	7	4-1/8	_____	168.00	_____	
Food, 2-piece						
303	4-3/8	3 ±1/8	_____	49.9	_____	
Tuna, large	2-1/4	3-3/4	_____	50.13	_____	
Tuna, medium	1-3/4	3-3/8	_____	31.97	_____	8.93
Tuna, small	1-1/2	2-1/2	_____	21.33	_____	

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EXHIBIT B-1 (Continued)

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CLEANED CAN CATALOGUE (CCC) TALLY SHEET (Cont'd)

Can Type	H (")	D (")	Body	Wt (gms)
Beverage				
3-piece				
Bimetal				
12 oz			_____	49.17
8 oz	4	2-3/8	_____	47.58
8 oz			_____	33.93
6 oz			_____	31.90
Steel				
12 oz (Nutrament)	4-7/8	2-5/8	_____	67.10
12 oz (V-8)	4-7/8	2-5/8	_____	55.30
6 oz			_____	34.75
2-piece				
12 oz			_____	37.05
6 oz			_____	32.62
Composite				
Biscuit, small		2	_____	3.78
Biscuit, large		2-1/4	_____	5.25
Orange juice, small		2-1/8	_____	6.05
Orange juice, large		3-5/8	_____	8.50
Oil, 1 qt			_____	17.14
Spray				
Small	5-1/2	2-1/8	_____	66.03
Medium	6-1/4	2-5/8	_____	106.85
Large, smooth	7-3/4	2-5/8	_____	118.15
Large, crimped	7-3/4	2-5/8	_____	131.15
Shaving cream	4-3/4	2-5/8	_____	84.57

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EXHIBIT B-1 (Continued)

CLEANED CAN CATALOGUE (CCC) TALLY SHEET (Cont'd)

Can Type	Side	H (")	D (")	Body	Wt (gms)
Other					
Pepper	4-1/2	2-1/2	1-7/8	_____	35.67
Spice	2-3/8	2-5/16	1-1/4	_____	22.98
Motor oil, 1 qt				_____	97.60
Bottlecaps				_____	2.055

Subtotal from above _____

Remaining material, cleaned _____

Total _____

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